

## Introduction

This technical note assumes a basic understanding of the operation of the PI-MAX2 and PTG in Gate Mode using WinView or WinSpec. Please refer to Chapter 7 of the PI-MAX/PI-MAX2 system manual if you do not feel confident with the basic operation of the PI-MAX and PTG in Gate mode.

The purpose of the PI-MAX2 DIF system is to acquire a pair of gated images in rapid succession. The time between frames can be as short as 2  $\mu$ s with exposure times as short as 5 ns. The DIF capability is ideally suited to capturing rapidly evolving events. These experiments will fall into one of two broadly applicable categories: single trigger and dual trigger experiments. Single trigger experiments involve a single impulse event that evolves over time such as a laser-induced plasma or luminescence decay. Dual trigger experiments involve two impulses separated in time such as double laser pulse velocimetry measurements.

## Requirements

The following requirements must be met for DIF operation:

- the PI-MAX2 must use an interline CCD,
- the controller must have a High Speed PCI Interface (TAXI) board and a PTG board installed, and
- the entire system must be set up for DIF operation at the factory.

In addition to these requirements, it is recommended that the intensifier have a fast decay phosphor (P46 or P47). Since DIF operation involves acquiring images in rapid succession, phosphor persistence can become the limiting factor in the rate of image acquisition.

WinView or WinSpec software (version 2.5.16 or later) can control the DIF functionality of the PI-MAX2 and provides full access to the two DIF timing modes: single trigger and dual trigger.

## Interline CCD Operation

An interline CCD consists of alternating columns of light sensitive pixels and storage pixels. The light sensitive columns are referred to as the active area and acquire the image. The storage pixels are called the masked area and store the image in the dark while it is read out. With this architecture, the CCD can acquire a second image while the first image is being read out, unlike a standard CCD, which must read out the first image before the second acquisition can begin. The ability of the interline CCD to quickly transfer an image under the masked columns and hold it there makes DIF possible. As soon as the first image is acquired,



it is shifted under the masked area and held. The second exposure begins and is held in the active area until the first image is read out.

## Timing Modes

In WinView and WinSpec, the timing modes available in the **Acquisition|Experiment Setup...|Timing** tab are different from those in standard intensified systems. The available timing modes are:

**Single Trig. Mode:** two shot, one trigger for both shots.

**Dual Trig. Mode:** two shot, each shot requires a trigger.

The trigger(s) can be generated by an external source attached to the PTG or the PTG can generate the trigger(s) internally. When using a PTG internal trigger, the experiment will normally be triggered by a signal from the ST-133. Typically, the rising edge of T0, from the PTG, is used.

### Single Trigger Mode

The Single Trigger Mode only requires a single trigger to initiate the acquisition of both images of the DIF operation. The Single Trigger Mode uses the Burst Mode feature of the PTG to acquire two images from a single trigger event. On the **Gating** tab of the Pulse dialog, the Burst Mode should be turned on. The Number of Pulses must be set to 2, and the time between the images is set by the Burst Period. It is very important that the Burst Period be large enough to accommodate the gate width, gate delay, and phosphor decay time. To set the gate width and delay, select Repetitive Mode from the **Gating** tab of the Pulse dialog and then click on the Setup button.

**Note:** Sequential Mode will not create different gate width and delay for the two images in Single Trigger Mode due to Burst Mode selection.

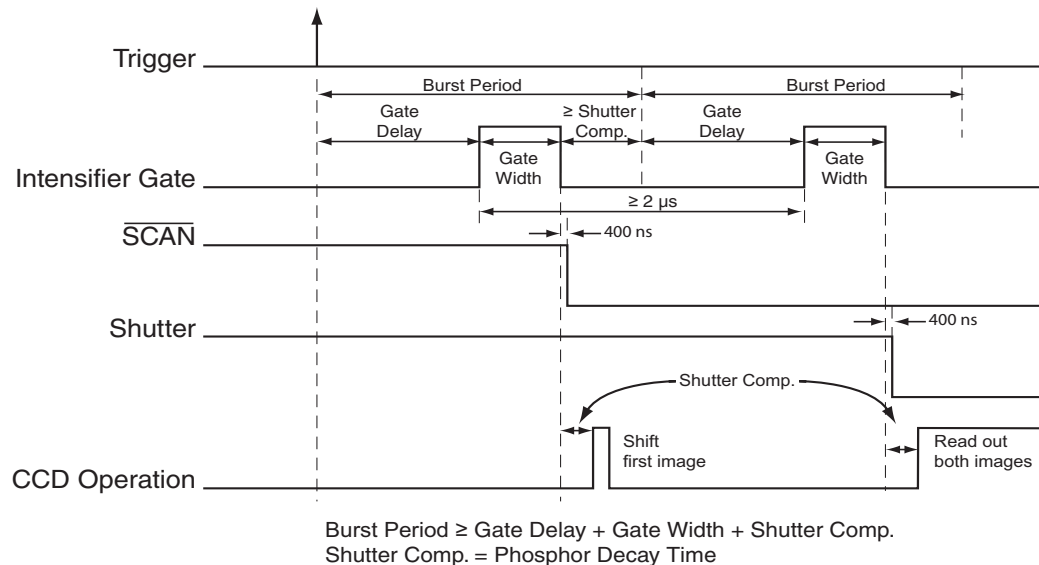


Figure 1. DIF Operation: Single Trigger Timing Diagram



## Dual Trigger Mode

The Dual Trigger Mode requires two triggers to acquire both images of the DIF operation. The PTG will control the gating of the intensifier for both images. To make the gate width and delay the same for both images, select Repetitive Mode from the **Gating** tab of the Pulser dialog then click the Setup button to set the values. To make the gate width and delay different for each pulse, select Sequential Mode from the **Gating** tab of the Pulse dialog, then click the Setup button to set the values. The Number of Images should be set to 2, and the first image will use the starting values for gate width and delay while the second image will use the ending values.

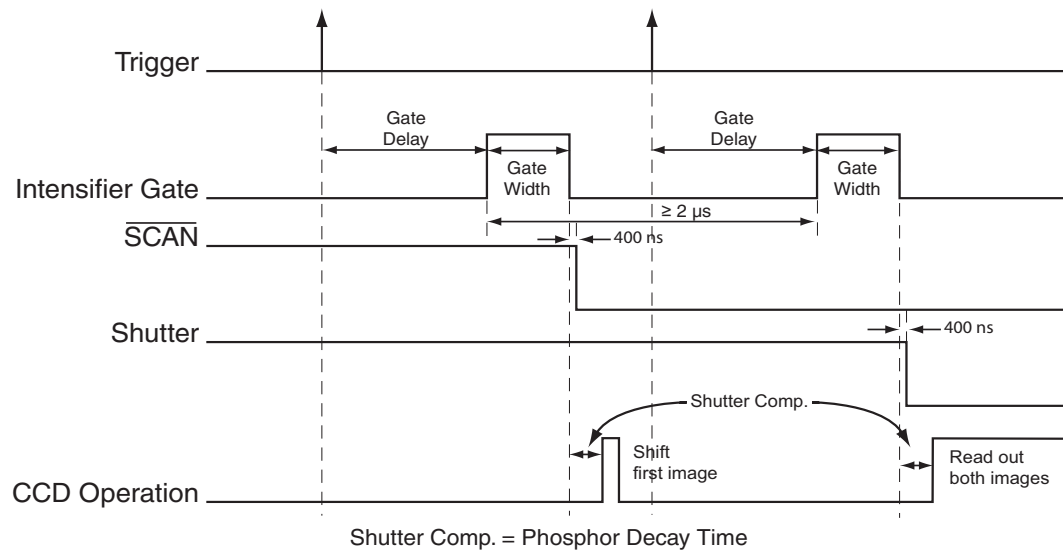
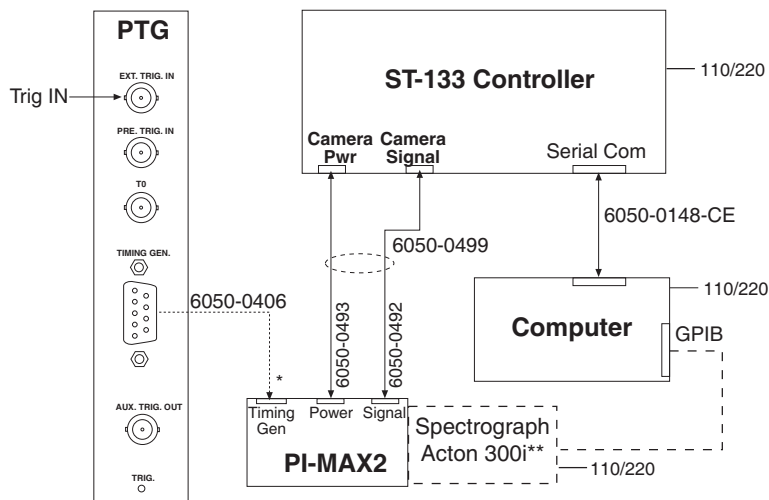


Figure 2. DIF Operation: Dual Trigger Timing Diagram



## Setup

### Hardware



\* In current systems, the Timing Gen. cable can remain connected during Shutter Mode operation. Older systems may require that it be disconnected.

\*\* Spectrograph connection is optional.

Figure 3. System Diagram: DIF Operation

### Software

For the purposes of this setup, it is assumed that you are using either WinView or WinSpec to control the system.

## Operation

The operation of the PI-MAX2 in DIF mode is similar to the standard operation of a PI-MAX2 with PTG. There are only a few differences due to the special timing modes of DIF, and they will be outlined here. Because there are two timing modes in DIF operation, there are two procedures for setting up the experiment.

### Single Trigger Mode

1. The first requirement is that the PI-MAX2 camera be aligned and focused on the area of interest in the experiment. This is best accomplished while the PI-MAX2 is operating in Interline mode (i.e., before switching to DIF mode). The procedure for initial focus is outlined in Chapter 4: First Light of the PI-MAX/PI-MAX2 system manual.
2. After the alignment and focus, the PI-MAX2 system needs to be put into DIF mode. Select **Hardware** from the **Setup** menu to open the Hardware dialog. Under Readout Mode, select **DIF** and then click **OK**.



3. The PI-MAX2 must be set to Gate mode for the intensifier to operate properly. Either click on the **Gate mode** button on the Custom Toolbar or select **Gate mode** on the **Acquisition|Experiment Setup...|Main** tab.
4. Now the PTG needs to be programmed to match the experiment. On the **Setup** menu, select **Pulser** and click on **Pulser Setup** (or click the **Pulser Setup** button in the Custom Toolbar).
  - a. In the **Pulser** dialog, select the **Trigger** tab. The PTG can be triggered by an external trigger signal such as a TTL (typical settings for a TTL trigger might be: 1.7 V, positive edge, DC, 50 Ohm) or a photodiode (typical settings for a photodiode might be: 8.0 V, positive edge, DC, high Z), or the PTG can use its own internal clock to trigger the experiment. Select the appropriate one for your experiment. In either case, the trigger frequency should be slow enough so that the period between triggers is longer than the entire DIF experiment. For example, if the Burst Period is 6  $\mu$ s, then the trigger frequency should be 8333 Hz [ $1 / (2 * 6 \mu\text{s})$ ].
  - b. Now select the **Gating** tab. In the Burst Mode section, turn Burst Mode on. Set the Number of Pulses to 2. The Burst Period must be set to a value that is greater than Gate Width + Gate Delay + Phosphor Decay. Ensure that the Gating is set to Repetitive, and then click on the **Setup** button to set the appropriate gate width and delay.
  - c. At the bottom of the **Pulser Setup** dialog, click **OK** to download the gating sequence to the PTG.
5. The CCD parameters need to be set to the appropriate values for DIF operation. Select **Experiment Setup** from the **Acquisition** menu.
  - a. In the **Timing** tab, select **Single Trig. Mode**.
  - b. In the **Main** tab, verify that the Number of Images is 2 and the Intensifier is in Gate Mode.
  - c. When the experiment is ready, click the **Acquire** button to start the image acquisition.

## Dual Trigger Mode

1. As with Single Trigger Mode, the PI-MAX2 camera must first be aligned and focused on the area of interest in the experiment. This is best accomplished while the PI-MAX2 is operating in Interline mode (i.e., before switching to DIF mode). The procedure for initial focus is outlined in Chapter 4: First Light of the PI-MAX/PI-MAX2 system manual.
2. The PI-MAX2 system needs to be put into DIF mode. In the **Setup** menu, open the **Hardware** dialog. Under Readout Mode, select **DIF** and then click **OK**.
3. The PI-MAX2 must be set to Gate mode for the intensifier to operate properly. Either click on the **Gate mode** button on the Custom Toolbar or select **Gate mode** on the **Acquisition|Experiment Setup...|Main** tab.



4. Now the PTG needs to be programmed to match the experiment. In the **Setup** menu, select **Pulser** and click on **Pulser Setup** (or click the **Pulser Setup** button in the Custom Toolbar).
  - a. In the Pulser dialog, select the **Trigger** tab. The PTG can be triggered by an external trigger signal such as a TTL (typical settings for a TTL trigger might be: 1.7 V, positive edge, DC, 50 Ohm) or a photodiode (typical settings for a photodiode might be: 8.0 V, positive edge, DC, high Z), or the PTG can use its own internal clock to trigger the experiment. Select the appropriate one for your experiment. In either case, the trigger frequency should be slow enough so that the period between triggers is longer than the Gate Delay + Gate Width + Phosphor Decay time.
  - b. Now select the **Gating** tab. If the experiment can use the same gate width and delay for both frames, then select **Repetitive**, and click on the **Setup** button to set the appropriate gate width and delay. If the experiment requires different gate widths or delays for each frame, then select **Sequential** and click on the **Setup** button to set the appropriate gate widths and delays. The number of images should be set to 2, the gate width and delay for the first frame should be set as the starting values, and the width and delay for the second frame should be set as the ending values.
  - c. At the bottom of the **Pulser Setup** dialog, click **OK** to download the gating sequence to the PTG.
5. The CCD parameters need to be set to the appropriate values for DIF operation. Select **Experiment Setup** from the **Acquisition** menu.
  - a. On the **Timing** tab, select **Dual Trig. Mode**.
  - b. On the **Main** tab, verify that the Number of Images is 2 and the Intensifier is in Gate Mode.
  - c. When the experiment is ready, click the **Acquire** button to start the image acquisition.

## Tips and Tricks

Experiments using the DIF feature of the PI-MAX2 can be complex, and timing of the events is usually rather exacting. Here are several points to consider that may make the experiment setup or troubleshooting much smoother and easier.

- The most important piece of equipment in a DIF experiment is an oscilloscope. The PI-MAX2 has a Gate Monitor signal on the back of the camera head which is very useful for seeing when the two image exposures occur during the course of the experiment. The use of the Gate Monitor and an oscilloscope is discussed in more detail in Chapter 11: Tips and Tricks.

**Note:** If you have an older version of the PI-MAX/PI-MAX2 system manual, refer to Chapter 10.

- The short time between the two images in DIF requires an intensifier with a fast phosphor. P46 phosphor has a decay time of  $\sim 2 \mu\text{s}$ , that means it takes 2  $\mu\text{s}$  for



the phosphor emission to drop to 10% of its peak value. The decay is not a simple single exponential; even after 100  $\mu$ s there may be 1% or more of the first image on the phosphor screen. It is usually possible to subtract a percentage of the first image from the second image to remove the residual image. If this is not possible, there are intensifiers with P47 phosphor, which is an order of magnitude faster than P46.

- The software uses the Shutter Compensation Time to determine how long to wait after the gate pulse to shift the image. This value can be adjusted in the Hardware Setup dialog. If there is some residual image from the first frame in the second frame, simply increase the Shutter Compensation Time to allow the phosphor more time to decay before shifting the image. If residual image is not an issue, then Shutter Compensation Time can be shortened to decrease the time between the two DIF images.



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